Influence of the Number of Predicted Words on Text Input Speed in Participants With Cervical Spinal Cord Injury

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TITLE: Influence of the number of predicted words on text input speed in participants with cervical spinal cord injury.

SHORT TITLE: Influence of the number of predicted words in persons with SCI

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ABSTRACT

Objective

To determine if the number of words displayed in the Word Prediction Software (WPS) list affects Text Input Speed (TIS) in people with cervical Spinal Cord Injury (SCI) and if any influence is dependent on the level of the lesion.

Design

A cross-sectional trial.

Setting

A rehabilitation center in France.

Participants

Ninety persons with cervical SCI fulfilled the inclusion/exclusion criteria, 45 of whom agreed to participate. Lesion level was high (C4 and C5 Asia A or B) for 15 participants (high lesion group) and was between C6 and C8 Asia A or B for 30 participants (low lesion group).

Methods

TIS was evaluated during 4. 10-minute copying tasks:

-without WPS (Without)

-with a display of 3 predicted words (3Words)

-with a display of 6 predicted words (6Words)

-with a display of 8 predicted (8Words)

Outcome Measures

During the 4 copying tasks, TIS was measured objectively (characters per minute, number of errors) and subjectively through subject report (fatigue, perception of speed, cognitive load, satisfaction)

Results

For participants with low cervical SCI, text input speed without WPS was faster than with WPS, regardless of the number of words displayed ($p<0.001$). For participants with high cervical SCI, the use of WPS did not influence TIS ($p=0.99$). There was no influence of the number of words displayed in a word prediction list on TIS, however perception of TIS differed according to lesion level.

Conclusion

For persons with low cervical SCI, a small number of words should be displayed, or WPS should not be used at all. For persons with high cervical SCI, a larger number of words displayed increases the comfort of use of WPS.

Key words

Cervical spinal cord injury, text input speed, word prediction software, words displayed

ABREVIATIONS:

SCI: Spinal Cord Injury

TIS: Text Input Speed

WPS: Word Prediction Software

CPM: Characters per minute

SD: Standard Deviation

Introduction

The use of technology is essential for the social and professional integration of persons with cervical spinal cord injury (SCI)[1]. Likewise, the emergence of new interfaces such as tablets and smartphones have changed how people communicate and use the Internet[2]. However, access to Internet and social websites, which is mainly based on text input, can be difficult, especially for persons with high cervical SCI. A variety of devices (infrared cameras, onscreen keyboards etc.) have been designed to facilitate computer use, depending on the level of the lesion [3 4.5.6.7.8.9]. Despite the use of these devices, text input remains laborious with a mean text input speed (TIS) of 5 words per minute[10] compared with 15-20 words per minute in able-bodied people [10]. Several methods have been developed to increase TIS[11 9 12 13 14.15], such as speech recognition systems[16] or word prediction software (WPS). These methods are recommended by health-related professionals[17] to increase TIS. However, in a noisy home environment, the use of a speech recognition system may be compromised. Also, some people want to keep their privacy when they dictate a text. Thus WPS may be a solution to compensate for some of the disadvantages of speech recognition software. WPS display a list of predicted words that correspond to the word currently being typed by the user. If one of the predictions is correct, the user selects the corresponding word in the list, thereby avoiding typing each letter of the word (keystroke saving[18]). WPS can be customized, for example by changing the number of words displayed.

Data in the literature are conflicting regarding the influence of WPS on TIS, with some studies showing decreases of up to 71% and others showing increases of up to 45% [19 20 21 22 23 24 25]. The main reason suggested for these differences is the increase in cognitive load caused by the visual search for words in the prediction list. This suggests that the number of words in the prediction list affects TIS.
A study in healthy people showed that keystroke savings are significantly related to the number of words displayed[26]. However, since selection time increases with the number of words in the list, the benefits provided by keystroke savings may be cancelled out. A simulation study showed that each additional word displayed in the prediction list increases search time by 150 milliseconds[27]. Moreover, there is only a slight increase in keystroke savings between 6 and 11 words. According to these studies, the best compromise between keystroke savings and cognitive load appears to be 5 or 6 words[27].
A preliminary study[17] carried out in our group showed that health–related professionals most frequently set 6 words for their patients, similarly to data in the literature. However, an unpublished study in our department showed that persons with cervical SCI tended to set a display of 8 words for themselves.

These results suggest that the number of words displayed in the predicted list is important, however, the optimal number has not yet been determined in a large sample of persons with cervical SCI.

The aims of this study were therefore to determine if the number of words in the predicted list influences TIS in a large population of persons with cervical SCI Asia A or B and if this number was influenced by the level of cervical lesion. Based on data in the current literature, we hypothesized that 6 words would be optimal.

Method

Participants

This prospective cross-sectional study was carried out between October 2013 and March 2014. Persons with cervical SCI followed up in the department of physical medicine and rehabilitation of a Teaching Hospital were included by a physician and an occupational therapist if they were over 18 years old, had a SCI between C4 and C8 Asia A or B, were computer users, could read and write French and were not regular user of WPS. They were excluded if they had cognitive, linguistic or visual impairments. The study was approved by the local ethics committee (CPP Ile-de-France, Saint Germain en Laye) and all subjects provided written informed consent before participation. Data collection was performed by an occupational therapist and took place in the department of physical medicine and rehabilitation in the teaching hospital in which the patient was recruited.

Participants were included in one of two distinct groups, depending on their lesion level:

-A high lesion group for persons with C4 or C5 Asia A or B tetraplegia

-A low lesion group for persons with C6, C7 or C8 Asia A or B tetraplegia.

The distinction between the high lesion group and the low lesion group was made because persons with lesions at or below C6 have sufficient wrist extension to use a standard keyboard[28].

Materials

To standardize the evaluation conditions, a Dell-XPS computer, equipped with a KeyVit Onscreen Keyboard and Skippy WPS were used. Skippy was chosen as it has been shown to be the WPS which is the most prescribed and used [17]. Participants who used an onscreen keyboard used their usual pointing devices (head-controlled).

The WPS was configured to display the list of words horizontally at the top of the screen, as is most frequent. The number of words (3, 6 and 8) was chosen based on results from our previous study on the use of WPS and data in the literature. Two parameters were not activated: automatic learning of new words and a faster presentation of the words most frequently used (frequency of use). It has been shown that most persons with cervical SCI use commercial WPS without such advanced settings[17]. Words were thus displayed alphabetically in the prediction list, as is the case in the majority of WPS.

Procedures.

Firstly, the use of WPS was explained to each participant. Then, each participant was allowed a 5 minute-training period using the WPS in a copying task. Finally, each participant underwent a single evaluation session involving 4 copying task conditions. The conditions were randomly assigned to avoid bias associated with fatigue:

-without WPS (Without)

-with 3 predicted words (3Words)

-with 6 predicted words (6Words)

-with 8 predicted (8Words)

The randomization was performed using dedicated software and a system of sealed envelopes was used for allocation. A maximum of 10 minutes was allowed for each task and participants were given a five-minute break between each task. Four 500-word texts of similar complexity were used, drawn from a speech and language therapy book[29]. The average word length was 5.1±0.5(SD). The length of each text was deliberately too long for it to be copied in 10 minutes. The evaluation was therefore stopped after 10 minutes. The texts were randomly allocated in order to ensure that the same text was not associated with the same copying task.

Participants were instructed to use the WPS but no instructions regarding strategies of use were given. Errors could be corrected.

All assessments were videotaped and the videos were used for the analysis. All the evaluations were performed by the same investigator to limit bias.

Outcome Measures.

During the 4 copying tasks, TIS was calculated as follows:

Objective evaluations

Characters per minute (cpm): Number of characters typed in ten minutes divided by 10, including punctuation marks, spaces, backspace, selection errors, and correction times.

Item selection speed (item per minute): Number of items selected in ten minutes divided by 10 including punctuation marks, spaces, backspaces, arrow keys and keys used to select words in the word prediction list.

Number of errors and **rate of word prediction use**: The number of errors and number of predicted words selected from the word prediction list in ten minutes were calculated from the videos.

Subjective evaluations (self-evaluations).

Fatigue was evaluated using a 0-10 point visual analog scale (VAS) before and after every task (0: no fatigue - 10: exhaustion)

Perception of speed and cognitive load were evaluated using a 0-10 point VAS. For perception of speed, 0: very slow - 10: very fast; for cognitive load, 0: low cognitive load - 10: high cognitive load.

Satisfaction was evaluated using a 0-5 point VAS (0: not satisfied/5: very satisfied)

Data Analysis

Descriptive statistics (mean±standard deviation) were used to describe continuous variables and frequencies for categorical variables.

A Wilcoxon test was used to analyze differences in age and education level between the low and high lesion groups.

A Chi square test was used to analyze differences in gender, frequency of use of word processing and frequency of computer use between the low and high lesion groups.

The objective and subjective data relating to TIS followed a normal distribution (Shapiro–Wilk-test) and thus parametric tests were used. To compare the influence of the number of words displayed in the prediction list on TIS, item selection speed, number of errors, rate of word prediction use, satisfaction, cognitive load and perception of speed, a repeated-measures ANOVA with two factors: type of assessment (Without/3Words/6Words/8Words) and lesion level (high/low) was used. A post-hoc Fisher's least significant difference (LSD) test was carried out on significant results. For the analysis of the high lesion group, we used a repeated-measures ANOVA with two factors: type of assessment (Without/3Words/6Words/8Words) and devices used (standard keyboard/onscreen keyboard + Trackball/ onscreen keyboard + Infrared camera). The level of significance was fixed at $p < 0.05$. Data were analyzed using STATISTICA 10 software-StatSoft. Inc software (Tulsa, USA).

Results

Demographic results

Ninety persons with cervical SCI fulfilled the inclusion/exclusion criteria, of whom 45 agreed to participate in this study (35 males and 10 females; mean age 39.6 (SD10) years). Mean time since lesion of the overall group was 10.6 (SD8) years.

Fifteen participants were included in the high lesion group (14 males and 1 female, mean age 40.9 (SD9) years). Ten participants had used a computer for over 10 years, 2 between 5 and 10 years, 2 between 1 and 5 years and 1 for less than 1 year. Six subjects used infrared tracking technology and 9 used a trackball controlled by the chin. All used onscreen keyboards. Thirteen subjects used word processing programs regularly (>3 times/week) and 2 did not (≤3 times/month).

Thirty participants were included in the low lesion group (21 males and 9 females, mean age 39.5 (SD11) years. Twenty-six participants had used a computer for over 10 years, 3 participants between 5 and 10 years and 1 between 1 and 5 years. All participants used a standard keyboard without splints and used word processing programs regularly (>3 times/week).

There were no significant differences between groups for age, gender, years of education and frequency of use of word processing programs. However, participants in the low lesion group used the computer more frequently than participants in the high lesion group ($p<0.001$).

Results of objective evaluations

TIS (Characters per minute)

------------------------------Insert table 1 ---

There was a significant effect of condition on TIS (Without/3Words/6Words/8Words)($F(3,129)=8.64; p<0.001$); there was also a significant effect of lesion level ($F(1,43)=27.6; p<0.001$) and a significant interaction between the 2 factors ($F(3,129)=8.89, p<0.001$).

The post-Hoc analysis indicated that participants with low lesions inputted text faster than participants with high lesions. For participants with low lesions, text input was faster without WPS than with WPS (3Words/6Words/8Words) regardless of the number of words displayed ($p<0.001$). For participants with high lesions, there was no influence of WPS (3Words/6Words/8Words) on TIS ($p=0.99$).

In the high lesion group, there was no significant effect of condition on TIS ($F(3,39)=0.2$; $p=0.89$); however, there was a significant effect of the device used ($F(1,13)=11,2$; $p=0.005$ with no interaction between the 2 factors ($F(3,39)=0.75$; $p=0.52$)

Number of Errors

------------------------------Insert table 2 ---

There was a significant effect of lesion level on the number of errors ($F(1,43)=35.3;p<0.001$). However, there was no influence of condition ($F(3;129)=0.9;p=0.43$) and no interaction between the 2 factors ($F(3,129)=0.18,p=0.90$).

The Post-Hoc analysis indicated that the high lesion group made fewer errors than the low lesion group ($p<0.001$). There was no influence of condition ($p=0.44$) on the number of errors in either group.

In the high lesion group, there was no significant effect of condition on the number of errors ($F(3,39)=1.5$; $p=0.22$), no significant effect of the device used ($F(1,13)=0.002$; $p=0.96$) and no interaction between the 2 factors ($F(3,39)=1.6$; $p=0.20$)

Item selection speed.

------------------------------Insert table 3 --

There was a significant effect of condition on item selection speed (Without/3Words/6Words/8Words)($F(3,129)=7.84;p<0.001$). There was also a significant effect of lesion level ($F(1,43)=28.76;p<0.001$) and a significant interaction between the 2 factors ($F(3,129)=11.11;p<0.001$).

The Post-Hoc analysis indicated that participants with high lesions had a higher key selection speed than participants with low lesions. Key selection speed was higher without WPS for participants with low lesions ($p<0.001$) whereas there were no differences between conditions for the high lesion group ($p=0.99$). In the high lesion group, there was no significant effect of condition on item selection speed ($F(3,39)=0.9$; $p=0.44$). However, there was a significant effect of the device used ($F(1,13)=9.8$; $p=0.007$) with no interaction between the 2 factors ($F(3,39)=0.8$; $p=0.49$)

Rate of word prediction use.

-----------------------------Insert table 4 ---

There was a significant effect of lesion level on rate of use of word prediction. ($F(1,43)=5.6$;$p=0.02$). There was no influence of condition ($F(2,86)=1.6$;$p=0.18$) and no interaction between condition and lesion level ($F(2,86)=2.6$,$p=0.07$). The Post Hoc analysis showed no interaction between low and high lesions ($p=0.33$) or between lesion level and condition ($p=0.99$). In the high lesion group, there was no significant effect of condition on rate of use of word prediction ($F(2,26)=1.49$; $p=0.24$); However, there was a significant effect of the device used ($F(1,13)=5.6$; $p=0.003$ with no interaction between the 2 factors ($F(2,26)=2.65$; $p=0.09$)

Results of the subjective evaluations

Fatigue

There was no significant effect of condition ($F(3,129)=1.86$);$p=0.97$) or lesion level ($F(1,43)=0.2$;$p=0.65$) and no interaction between the 2 factors ($F(3,129)=1.86$;$p=0.13$).

Perception of TIS

There was a significant effect of condition ($F(2,86)= 4.91$; $p<0.001$) and lesion level ($F(1,43)= 6.82$; $p=0.01$) with no interaction between the 2 factors ($F(2,86)=2.34$; $p=0.10$).

The Post-Hoc analysis indicated that, for the low lesion group, participants perceived text input as faster with a display of 3 words compared to 8 words ($p=0.003$). Participants with high lesions perceived text input as faster with a display of 6 and 8 words than participants with low lesions (respectively $p=0.03$;$p<0.001$).

Cognitive load

There was no influence of condition ($F(2,86)=1.42$;$p=0.24$) or lesion level ($F(1,43)=0.91$;$p=0.35$) and no interaction between the 2 factors ($F(2,86)=1.33$;$p=0.26$).

Satisfaction

There was no influence of condition ($F(2,86)=0.31$;$p=0.73$). There was a significant effect of lesion level ($F(1,43)=5.97$;$p=0.02$) and a significant effect between the 2 factors ($F(2,86)=3.25$;$p=0.04$). The Post-Hoc analysis indicated that for the high lesion group, satisfaction with 8 Words was higher than for the low lesion group ($p=0.01$)

Discussion

We found in this study that the influence of WPS on text input speed depended on the lesion level of the user. TIS was faster without WPS for participants with low lesions, whatever the number of words displayed, while there was no influence of WPS in participants with high lesions. These results refute our hypothesis and contrast with previous results in the literature.

Influence of WPS on TIS.

The influence of WPS on TIS differed depending on the level of cervical SCI. This result was further confirmed by the rate of word prediction use in each group.

In each group.

For the low lesion group, the decrease in TIS with WPS was associated with a decrease in key selection speed, even if the cognitive load was not higher with WPS in this group. However, this is in accordance with previous studies[19.22] and could relate to the necessity to search for predicted words on the computer screen while using a physical keyboard.

For the high lesion group, TIS, item selection speed and cognitive load were not affected by WPS, whatever the device used. These results therefore suggest that not only is the use of WPS not effective to increase TIS in people with cervical SCI, it may actually have a negative influence on TIS. However, the adjustment of other settings could change the influence of WPS on TIS. In another study conducted by our team (in press), we showed that the activation of “frequency of use” increased TIS in persons with high cervical SCI. The difference in results between the two groups may relate to the fact that the cognitive load induced by the visual search for words in the prediction list is lower with the use of an onscreen keyboard since a smaller degree of visuospatial exploration is required than for a standard keyboard (used by the low SCI level group). Tam et al (2009) confirmed this hypothesis since they found that people with cervical SCI who used an external device to display the word prediction list near the standard keyboard had to look at their fingers when they typed[30].

Between group comparison

There were fewer text input errors in the high lesion group than the low lesion group. This could be the result of the lower TIS of the high lesion group along with the fact that use of an onscreen keyboard requires a smaller degree of visuospatial exploration.

The lack of influence of WPS on fatigue in both groups contradicts data in the literature. WPS has previously been shown to reduce fatigue in persons with cerebral palsy[31]. This difference might be related to the fact that persons with cervical SCI have lower levels of fatigue than persons with brain injury. This should, however be evaluated in further comparative studies. The results of the present study may also have been affected by the fact that the “frequency of use” and “learning new words” parameters were disabled. This could affect TIS, fatigue and the number of errors. It would therefore be interesting to study the influence of these parameters more specifically in future studies.

Influence of the number of words displayed on TIS.

We initially hypothesized that the number of words displayed in the prediction list would influence TIS. However, there was no influence of the number of words displayed on TIS or on key selection speed in either group, whatever the device used. Similarly, there was no influence on rate of word prediction use. These results contrast with previous results in the literature. Koester found that a display of 5 or 6 words is the best compromise between increasing TIS and cognitive load[27]. This difference may be related to differences in methodology and the fact that the sample of participants with cervical SCI was larger in the present study. Participants with low lesions perceived text input to be faster with a display of 3 words rather than 8 words. This may be related to the fact that a shorter list requires a shorter visual search time. In contrast, satisfaction was higher with a display of 8 words for participants with high lesions. The higher TIS of participants with low cervical SCI may make reducing visual search time a priority while the use of a virtual keyboard by participants with high lesions and the low associated TIS may induce a preference for a greater choice of words and greater key stroke savings. However, it must be noted that altering the number of words displayed only affected the perception of TIS but had no objective influence.

Study limitations

The difference in the number of subjects and the difference in the frequency of computer use in the high and low cervical SCI groups could constitute a bias in the interpretation of the results. However, any such bias appears to have had a minimal impact since the variability of the two groups was almost similar. No studies found in the literature have evaluated the influence of lesion level on TIS. This study on word prediction software involved the largest sample of persons with cervical SCI currently available in the literature and thus the results are worthy of note.

Moreover, the use of different computer access devices in the high lesion group influenced text input speed and item selection speed. Nevertheless, the results suggest that the impact of these different devices on the influence of word prediction software and the number of words displayed was small. We found no influence of the number of words displayed on TIS in the high lesion group, and no influence of the WPS on TIS as a function of the type of device used. In addition, the lack of validation of the visual analogue scales used may constitute a limitation for the analysis and the interpretation of results.

The alteration of other parameters such as the frequency of words displayed may influence TIS by increasing the relevance of the displayed words. Moreover, lack of training in the use of WPS could also influence TIS. The influence of training should be considered in future studies.

Conclusions

The influence of the number of words displayed in a word prediction list on TIS differed depending on the level of cervical SCI. The use of WPS decreased TIS in participants with low lesions, whatever the number of words displayed. In participants with high lesions, there was no influence of WPS on TIS and no influence of the number of words displayed. The results of this study suggest that changing the number of words displayed may alter the perception of ease of text input in persons with SCI but does not have an objective influence on TIS. Further studies should be carried out to evaluate the influence of other WPS parameters on TIS. These results are important for health-related professionals whose role is to advise persons with SCI in the choice of word prediction software. It seems important to reduce the number of words displayed for persons with low cervical SCI, or not to use WPS at all, and to increase the number of words displayed for persons with high cervical SCI in order to increase the comfort of use of WPS. However, it must be kept in mind that these results are based on a single data collection session. It would be useful to evaluate the impact of specific training on the influence of WPS. The impact of other parameters of word prediction software should also be considered in further studies, such as the location of the prediction list and the feature of only suggesting words of 5 characters or more, to decrease visual search time.

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TABLES

Table 1. Characters per minute – Mean (sd)

Table 2. Number of errors – Mean (sd)

Table 3. Key selection speed (key presses per minute) – Mean (sd)

Table 4. Rate of word prediction use– Mean (sd)